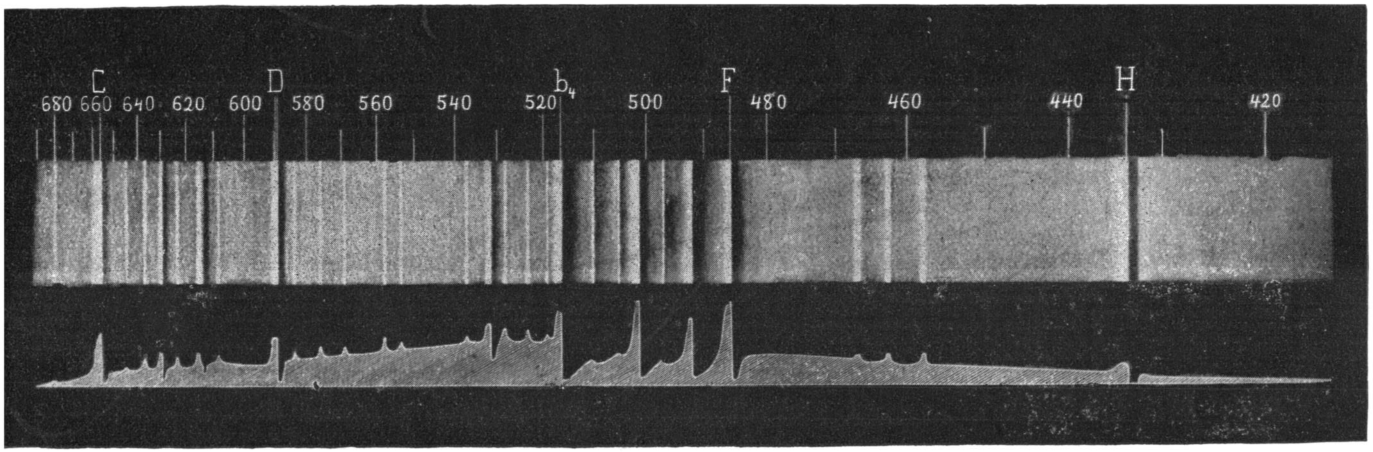


VISIBLE SPECTRUM OF *NOVA AURIGÆ*, FEBRUARY 28, 1892.

(From *Astronomy and Astro-Physics* for November, 1892.)

It thus appears that the star became bright quite suddenly about December 9, and reached its maximum brightness the latter part of December, a full month before its discovery.

Addendum.—On November 19, using the 36-inch equatorial, Mr. CAMPBELL estimated that *Nova* was $0^{m}.3$ brighter than in August, comparisons at both dates having been made with the star *h*.

THE SPECTRUM OF *NOVA AURIGÆ.*

BY W. W. CAMPBELL.

The discovery of a new star in the constellation *Auriga* has been the astronomical event of the year. Never before were all the available resources of so many observatories turned instantly from their various lines of work to the study of one object. The discoverer, Dr. THOMAS D. ANDERSON of Edinburgh, an amateur observer, with a small hand telescope magnifying ten times, observed the stranger several times in the last week of January, under the misapprehension that it was 26 *Aurigæ*. On the morning of January 31 he noticed that 26 *Aurigæ* was further east; and consulting a chart of that region the discovery was made that the star was "new." Thinking the star might be well known to astronomers, he at once wrote an *anonymous* postal card to the Astronomer Royal for Scotland, as follows: "*Nova in Auriga*, in Milky Way, about two degrees south of χ *Aurigæ*, preceding 26 *Aurigæ*." The discovery was verified by Dr. COPELAND on February 1, and the unique character of its spectrum was recognized. The discovery was immediately announced, telegraphically, and at nearly every observatory systematic observations of the star began at once.

The announcement of the discovery reached Mt. Hamilton February 6, and an outline of the different series of observations undertaken here was printed at that time in the *Publications*, pp. 84–85. The rapid decline of the star in brightness brought the observations to a close in March and April. But turning the great telescope upon the region occupied by *Nova*, on August 17, we were surprised to find it bright again, of the 10.5 magnitude, and thus began a new chapter in the history of this remarkable object. Both spectroscopic and visual observations

show that it is now a planetary nebula. [An account of this reappearance is given on p. 192 of the *Publications.*]

A series of observations of the magnitude of *Nova* after February 6 was secured here; and these, complemented by earlier observations secured elsewhere, will be found in the preceding paper on *Visual Magnitudes of Nova Aurigæ.* The present paper relates to spectroscopic observations made by me on seven nights between February 8 and March 13 inclusive, which will be treated under the heading of "The February and March Spectrum;" and to those made since August 17, which will be treated under the heading of "The Present Spectrum."

THE FEBRUARY AND MARCH SPECTRUM.

The observations, both visual and photographic, were made with the large BRASHEAR spectroscope and 36-inch equatorial. In the visual observations the 10½-inch view telescope and an eye-piece magnifying 13.3 times were used. The third and fourth orders of a grating of 14,438 lines to the inch were not found suitable for the study of this spectrum, principally on account of the strength of the continuous spectrum and the great breadth of lines. The Observatory did not then possess first and second order gratings, which could probably have been used to advantage. A dense thallium compound prism, dispersing 12° between B and H, was used on several evenings in fixing the positions and examining the character of the bright hydrogen lines, the D sodium lines, and a few other important lines. But an excellent 60° dense flint prism by BRASHEAR, dispersing 5½° between B and H, was for several reasons better adapted to a general determination of the wave-lengths, and was usually employed. With this prism the power of the spectroscope is such as easily to separate b_3 and b_4 in the solar spectrum, which are 1.6 tenth-metres apart.

In the photographic observations the eye-piece and micrometer were replaced by a camera-box suitable for holding a small plate-holder. No other changes were required to adapt the spectroscope to photography. In the winter I had decided to apply photography to spectroscopic work here; and, fortunately, on February 5 I had fitted the camera-box and determined the photographic focus. It is to be regretted that the Observatory did not then possess apparatus suitable for photographing the spectrum with greater dispersion than that given by the 60° prism.

THE VISIBLE SPECTRUM.

The general character of the visible spectrum is shown in the accompanying drawings of the spectrum and of the intensity curve, though in the former the contrast between the faint lines and the continuous spectrum was necessarily overdrawn. Many of the lines between D and F were so nearly masked by the continuous spectrum that under stronger dispersion they would have escaped detection entirely. The region between F and Hγ was seen to contain a large number of bright lines. A few of the more prominent ones were located on the first evening; but two photographs taken later on the same evening showed the lines in this region so satisfactorily that thereafter no effort was made to observe them visually. The drawing, therefore, really refers only to the portion of the spectrum below and including the F region, and is based upon the observations of February 8, 9 and 28. The intensity curve was drawn almost wholly from sketches made February 28, when the continuous spectrum had faded slightly, unmasking many of the lines previously invisible. On March 13, the continuous spectrum had in many regions wholly disappeared, and interfered with only a few of the measurements. A line at λ 5885, observed on the latter date only, is not shown in the drawing.

Altogether there were observed visually thirty bright lines, not counting a bright region at λ 432 and a faint line occasionally glimpsed near λ 680; and ten broad dark lines in contact with the more refrangible edges of ten of the strongest bright lines. Careful searches for lines below C were made, but only the trace of a line near λ 680 could be seen. In each of the ten dark lines, except that above Hγ, a background of continuous spectrum was still visible, and was so noted on several evenings. These lines were sharply defined below by the bright lines, but were diffuse above. They were from twelve to fourteen tenth-metres broad, and their centres were about eleven tenth-metres more refrangible than the most intense points in the corresponding bright lines. But the dark and bright lines evidently overlapped, and it is probable that their real centres were slightly less refrangible than their apparent centres. Possibly the real centres were near the fine bright lines shown in the photographs, which will be referred to later.

It was seen, first of all, that the normal positions for the hydro-

gen C, F and Hγ lines and the D sodium lines were occupied by bright lines. These and the lines λ 5168 and 5016 were carefully studied to obtain very accurately their positions and light curves. On the first few evenings all these lines were examined with the compound prism and extremely narrow slit, but no evidence of doubling was obtained; though with the exception of the D lines they were certainly very far from being uniformly bright throughout their breadth. The hydrogen lines C, F and Hγ, and the lines λ 5168, λ 5016 and λ 4923 were at least fifteen tenth-metres broad. Their more refrangible edges were quite sharply terminated. From the most intense points, which were about four tenth-metres below the upper edges, the intensity decreased about as shown in the drawing of the intensity curve, finally gradually merging into the continuous spectrum. The bright D line was about fifteen tenth-metres broad, quite sharply defined above, nearly uniform in brightness for ten or twelve tenth-metres, then merging gradually (but more sharply than the others) into the continuous spectrum below. The D line had greatly decreased in brightness by February 28; on March 13 it had apparently disappeared, and a faint line more refrangible than D was observed at λ 5885. The appearance of the spectrum at this point had changed considerably.

The points of maximum intensity in the C, F and Hγ bright lines were well enough defined to permit their wave-lengths to be determined within one tenth-metre, as was found by first setting the micrometer wire on the star lines and then throwing in the hydrogen comparison spectrum. These comparisons were made on several nights, and the star lines were found to coincide with the comparison lines within the limits stated above. I therefore adopted for the wave-lengths of these lines their usual values 6563, 4862 and 4341. On three nights the D star line and the D sodium lines of the spark spectrum and of the flame were carefully compared. With the compound prism and narrow slit the comparison lines were widely separated. When the micrometer wire was placed in contact with the upper edge of the star line it was also in contact with the upper edge of D_2. The comparison line D_1 appeared to fall in the exact centre of the broad star line, and I have accordingly adopted for it the wave-length 5896. The point of maximum brightness in the line λ 5168 was not well defined; but comparisons with magnesium b_4 showed that the wave-lengths were practically equal. The regions of maximum

brightness in the lines λ 5016 and λ 4923 were likewise quite broad, which made an accurate determination of their wave-lengths impossible.

Assuming the wave-lengths either of the comparison lines or of the star lines at λ 6563, λ 5896, λ 5168, λ 4862 and λ 4341, the wave-lengths of the intermediate lines were generally obtained from the readings of the large circle (12 inches in diameter, reading to 10″) corresponding to the different lines in the star, by interpolating between the assumed wave-lengths by means of curves based upon the solar spectrum. In some cases the wave-lengths could probably have been obtained more accurately by making micrometer comparisons, but usually the method employed was the most satisfactory for this spectrum. The wave-lengths resulting from the visual observations on five nights are given below. The appearance of a line depended upon its breadth, intensity, and position in the continuous spectrum, and it is impracticable to give a verbal description of the lines in this place. Reference can be made to the general intensity curve.

WAVE-LENGTHS OF BRIGHT LINES OBTAINED VISUALLY.

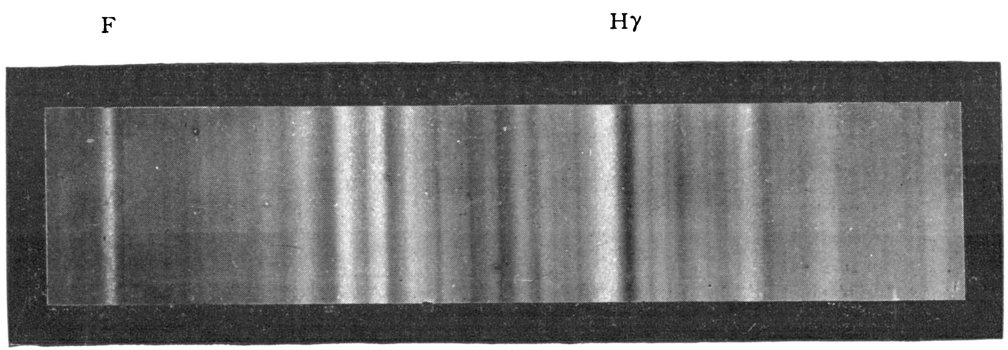
Feb. 8	Feb. 9	Feb. 22	Feb. 28	March 13	Means
....	....	....	[680]	...	[680]
6563	6563	6563	6563	6563	6563
6447	....	....	6456	....	6451
6363	6380	....	6367	6367	6369
6294	6299	....	6296	6295	6296
6251	6236	....	6234	...	6240
6151	6156	....	6158	...	6155
....	....	...	6087	...	6087
5896	5896	5896	5896	....	5896
....	....	....	...	5885	5885
....	....	....	5841	....	5841
....	...	....	5759	5763	5761
....	....	....	5690	....	5690
5585	5576	....	5575	5576	5578
....	....	...	5535	....	5535
5376	5372	....	5375	5390	5378
5320	5317	....	5321	5313	5318
5282	5282	....	5281	5274	5280
5229	5228	....	5237	5233	5232
5193	....	....	....	5193	5193
5167	5168	5168	5168	5168	5168
5103	5101	....	....	5103	5102
5056	....	...	..	5055	5055
5016	5013	5015	5016	5012	5014
4969	4972	....	4965	...	4969
4926	4922	....	4925	4921	4923
4862	4862	4862	4862	4862	4862
4670	....	....	....	....	4670
4629	...	....	....	....	4629
4583	4584	4582	....	....	4583
4341	4341	....	4341	4341	4341
....	....	....	[432]	....	[432]

THE PHOTOGRAPHIC SPECTRUM.

The 36-inch telescope is not suitable for a general study of the photographic portions of stellar spectra. Only a very limited region of a stellar spectrum can be photographed at one time to advantage, for the reason that the color curve of the 36-inch objective is very steep in the blue and violet, and only a few of the rays enter the slit. The focal length of the objective is 37mm. greater for the Hγ rays than for the F rays, and 34mm. greater for the Hδ than for the Hγ rays. For a given position of the spectroscope slit the rays of a certain wave-length come to a focus (a point) on the slit and pass through properly; those of greater wave-length are in focus before reaching the slit, and only a few of them pass through; those of smaller wave-length do not reach their focus, and only a few of them pass through the slit. Beyond Hδ the curve is so steep as practically to prevent the taking of photographs in this region. Another serious difficulty enters in this region of the spectrum: the image formed on the slit plate by the brighter visual rays is large and interferes very greatly with keeping the point in focus in the slit.

The photographs of *Nova Aurigæ's* spectrum were taken in two sections and with two sets of adjustments: first, with the slit in the focus for the F rays and the prism at minimum deviation for F; second, with the slit in the focus for the Hγ rays and the prism at minimum deviation for Hγ. In the first case the F rays proceeding from all parts of the object-glass entered the slit, while of the rays of greater or less wave-length only those proceeding from a region of the object-glass along and near the diameter parallel to the slit entered the slit at all. A similar result obtained for the Hγ setting. With ordinary dry plates the F photographs extend from the slightly actinic region λ 5200 to λ 4300, and are densest near and above F; and the Hγ photographs from λ 5000 to λ 4100 and densest in the Hγ region. One successful F photograph was obtained on an isochromatic plate, on February 14, which is measurable from λ 5686 to λ 4341. It is evident that the relative photographic brightness of lines in different parts of the spectrum cannot be obtained from these plates.

With the above limitations the photographs were successful from the first, and in all seven measurable negatives were obtained. A list of them is given below:



PHOTOGRAPHIC SPECTRUM OF *NOVA AURIGÆ*, FEBRUARY 9, 1892.

(From *Astronomy and Astro-Physics* for November.)

Date.		Region.	Slit Width.	Exposure.	Remarks.
1892, Feb.	8	F	0.0020 inch	15m	
	8	Hγ	0.0020	15m	
	9	F	0.0015	32m	
	9	Hγ	0.0015	26m	
	14	F	0.0011	37m	
Mar.	6	F	0.0010	120m	Very windy.
	6	Hγ	0.0010	150m	Very windy.

The spectrum of hydrogen was photographed on each plate for purposes of comparison, very near the stellar spectrum; on one side of it before beginning the exposure on the star and on the other side after closing the exposure. The original negatives were measured by means of a STACKPOLE measuring engine, and the measures were converted into wave-lengths by the aid of photographic interpolation curves. A list of the wave-lengths of bright lines obtained from each of the plates is given below. The results are corrected for the observer's motion and for curvature of the comparison lines. In a few cases it is impossible to determine from the negatives whether the lines measured were bright lines or were strong continuous spectrum between dark lines. In order to test the adjustments of the instrument, the lunar and hydrogen spectra were frequently photographed on the same plate, likewise the solar and hydrogen spectra, with the hydrogen tube both in front of the slit and at one side, and no displacement could be observed. A photograph of the spectrum of α *Orionis* showed the lines to be fine and sharp, while with the same adjustments and settings those of *Nova's* spectrum were broad and diffuse.

WAVE-LENGTHS OF BRIGHT LINES OBSERVED PHOTOGRAPHICALLY.

Feb. 8 F	Feb. 8 Hγ	Feb. 9 F	Feb. 9 Hγ	Feb. 14 F	Mar. 6 F	Mar. 6 Hγ	Means.	Remarks.
.....	......	......	......	5685	......	......	5685	Maximum in broad line.
......	......	......	......	5630	......	......	5630	Maximum in broad line, poorly defined.
......	......	......	.....	5584	......	......	5584	Two prominent lines, clearly separated.
......	.....	......	......	5575	.....	......	5575	
......	......	......	......	5534	.....	......	5534	Maximum in broad line.
......	......	.....	.....	5454	.....	......	5454	Maximum in broad line.
......	......	......	....	5379	.....	.....	5379	Maximum in broad line.
.....	.....	......	......	5329	......	......	5329	Double line very similar to F line.
......	......	......	......	5318	......	.....	5318	
......	.....	......	......	5285	.....	......	5285	Prominent line, probably double, but not clearly separated.
.....	.....	......	......	5276	......	......	5276	
......	......	......	......	5234	.....	......	5234	Very faint, poor.

Feb. 8 F	Feb. 8 $H\gamma$	Feb. 9 F	Feb. 9 $H\gamma$	Feb. 14 F	Mar. 6 F	Mar. 6 $H\gamma$	Means.	Remarks.
......	......	......	......	5200	......	......	5200	Very faint, poor.
......	......	......	......	5176	.....	......	5176	Similar to F line, double, but not
......	......	5170	......	5168	5170	......	5169	clearly.
......	......	......	......	5159	......	.....	5159	Very faint companion to above.
......	......	.....	......	5142	.... .	.....	5142	Very faint line.
......	......	....	......	5095	......	.....	5095	Faint line, poor.
5017	......	5019	.....	5018	5018	.....	5018	Similar to F line. no signs of doubling.
......	......	trace	.....	5007	trace	......	5007	Companion to above.
4969	......	trace	....	4969	4969	......	4969	Faint, poorly defined.
......	......	......	......	.....	4929.1	......	4929	Well defined March 6, equal to line below.
4922	......	4923	4923	4922.9	4921.7	4923	4923	Maximum of line resembling F line.
trace	......	trace	......	4913.2	4913.0	......	4913	Companion to above.
......	4871.3	....	4871.2	4868.9	4868.2	....	4869.9	Well defined March 6.
4861.7	4862.2	4861.4	4861.8	4861.1	4860.8	4862	4861.6	Principal F line.
4851.6	......	4851.8	4851.6	4852 0	4849.1	......	4851.2	Companion to above.
4777	.....	4772	......	4773	......	.....	4774	Estimated centre of very broad bright region.
4733	......	4739	......	4739	......	......	4737	Estimated centre of very broad bright region.
4700	......	4703	4715	4709	......	4710	4707	Estimated centre of broad bright region.
4671	.....	4666	4672	4669	. .	4668	4669	Centre of broad bright line.
4628	4632	4628	4631	4630	4631	4630	4630	Centre of broad bright line.
4588	4588	4587	4586	4587	4581	4585	4586	Centre of broad bright line.
4575	......	4576	4576	......	......	......	4576	Either well defined bright lines or
4570	.....	4570	......	......	......	.....	4570	continuous spectrum between absorption lines.
.....	......	4564	4565	4564	......	......	4564	A group of lines, defined on fourth
4556	....	to	4559	......	......	4561	....	and fifth negatives, blended on the
to	4553		4554	4556	4554	to	4554	others.
4546	.....	4547	4549	4549	.. ..	4545	...	
4533	4533	4538	4524	4538	......	4528	....	
to	to	to	to	to	4516	to	4518	Appears like a group of lines, but not
4504	4504	4500	4509	4511	......	4504	....	well defined.
4490	.....	4493	4494	......	......	4496	....	
4483	......	to	to	4479	4480	to	4481	A group of lines not well separated, with maximum about λ 4481.
4469	.....	4478	4470	......	.... .	4469	....	
.. ..	......	4455	......	......	.....	......	....	
4446	......	to	4445	4444	......	4446	4445	A group of lines with maximum about
......	......	4441	.....	......	.....	......	....	λ 4445.
.....	......	4436	4437	......	.....	......	4436	Broad bright line.
4421	......	4420	4418	4418	.....	4420	4419	Maximum of broad line.
4383	......	......	4386	......	......	4387	4385	Centre of bright region, apparently containing several lines.
......	......	4374	......	......	......	4376	4375	Rather broad line.
......	......	......	......	......	......	4355	4355	Apparently a third component of $H\gamma$ line.
.. ...	4347.9	4348.0	4348.9	4347.9	......	4346.2	4347.8	Component of $H\gamma$ line, usually well defined.
4340.8	4340.2	4340.7	4341.5	4340.6	......	4340.1	4340.6	Principal $H\gamma$ line.
4332.1	4332.2	trace	4331.5	trace	......	4329.4	4331.3	Companion to above.
......	......	......	4316	......	......	......	4316	Broad, appears double.
.....	4296	......	4297	......	.....	.....	4296	Broad, well defined.
......	4266	....	4269	......	.....	.....	4267	Centre of broad line.
......	......	......	4246	......	......	......	4246	Broad diffuse line.
......	4238	......	4234	......	......	......	4236	Broad bright line, resembles F and $H\gamma$ groups.
......	.... .	......	4227	.....	.....	......	4227	Faint companion to above.
......	......	......	4209	.....	......	......	4209	Broad diffuse line.
......	......	. ...	4180	......	......	......	4180	Very bright line.
......	......	......	4166	......	......	.....	4166	Broad defined line.
......	......	......	4126	.....	......	......	4126	Broad defined line.
......	......	......	4108	....	......	......	4108	Component of $H\delta$.
......	......	......	4102	......	......	......	4102	Principal $H\delta$ line.
.....	......	......	4095	. ...	......	......	4095	Companion to $H\delta$.
......	......	......	4082	......	......	......	4082	Maximum of broad line.

An enlargement of the $H\gamma$ photograph of February 9 is shown in the plate. A few defects in the original negative, mostly in the region of F, have been made to appear as lines by the cylindrical lens used in enlarging.

IDENTIFICATION OF THE LINES.

It was early noted by Professor VOGEL and others that the half-dozen prominent lines in *Nova's* spectrum coincided with prominent lines in the spectrum of the solar chromosphere. The probability that any line would be observed is a function of its intensity and the frequency with which it occurs, and therefore of the product of these two quantities. In the following table I have arranged a list of chromosphere lines whose wave-lengths agree closely with those of the lines in *Nova's* spectrum, placing opposite them the name of the element from which they originate, and the product of F $\times$ I of their frequency and intensity. They are selected from Professor YOUNG'S catalogue of 273 chromosphere lines, as given in SCHEINER'S *Spectralanalyse.* A few of the identifications are doubtful and are enclosed in brackets [ ]. The faint and infrequent chromosphere lines are not inserted in the list. It appears that nearly all the prominent lines in *Nova Aurigæ's* spectrum are prominent lines in the chromosphere spectrum, and *vice versa.* In the last two columns of the table are given a few other probable identifications. Many of the lines left unidentified fall near prominent lines or groups of lines in the spectrum of iron; while practically all of the lines can be matched by lines in the spectra of those elements which are prominent in the chromosphere. As surmised by Professor YOUNG, in *Astronomy* and *Astro-Physics* for April, the lines λ 6296 and λ 5578 are near the auroral lines λ 6298 and λ 5571. Likewise, the lines λ 5378, λ 5232, λ 5196, λ 4630 and λ 4355 are near other auroral lines; but the presence of so many iron lines in the spectrum renders it probable that these also are iron lines.

Nova Aurigæ		Chromosphere Lines.			Other Lines.	
Visual	Photographic	λ	F x I	Element	λ	Element
[680]	....	....	....	....	....	....
6563	....	6563	10000	Hydrogen	....	....
6451	....	[6455]	60	....	6451	Calcium
6369	....	....	....	....	..	....
6296	....	...	....	....	6303–98	Iron
6240	....	[6247]	40	Iron	...	....
6155	....	...	....	....	6161–55	Sodium
6087	....	.	....	....	....	....
5896	....	{5896} {5890}	1500 1500	Sodium Sodium	...	....
5885	....	[5876]	9000	Helium	....	....
5841	....	....	....	....	....	....
5761	....	....	....	....	....	....
5690	5685	....	....	....	5688–83	Sodium
....	5630	....	....	....	....	....

Nova Aurigæ		Chromosphere Lines.			Other Lines.	
Visual	Photographic	λ	F x I	Element	λ	Element
5578	{5584	....	....	....	5587	Iron
	5575}	....	. .	....	5576–70	Iron
5535	5535	5535	600	Iron	....	....
....	5454	5456–47	80	Iron	....	....
5378	5379	[5372]	30	Iron	....	....
5318	{5329	5317	4500	Iron, Cor.	....	....
	5318}	5317	4500	Iron, Cor.	....	....
5280	{5285	5285	200	Iron	....	....
	5276}	5276	450	Iron	....	....
5232	5234	5235	80	Iron, Mn.	.. .	....
5193	5200	5198	150	....	....	....
5168	{5176	5184–72	3250	Magnesium	....	....
	5169	5169–68	1800	Iron, Mg.	....	....
	5159}			....	....	....
....	5142	....	....	....	....	....
5102	5095	...	....	....	....	....
5055	trace	....	....	....	....	....
5014	{5018	{5019	450	Iron	....	....
	5007}	5016}	300	Titanium	....	....
4969	4969	....	....	....	....	....
4923	{4929	4924	480	Iron	....	....
	4923	...	....	....	....	....
	4913}	4919	60	Iron	....	....
4862	{4869.9			....	....	....
	4861.6	4861.6	8000	Hydrogen	....	....
	4851.2}			....	....	....
....	4774	....	....	....	....	....
....	4737	....	....	....	...	....
....	4707	....	....	....	4705	Magnesium
4670	4669	....	....	....	4669–65	Sodium
4629	4630	4630	270	Iron	4629	Cerium
4583	4586	4584	90	Iron	...	....
....	4576	....	....	....	[4573]	Cerium
....	....	....	..	....	[4572]	Titanium
....	4570	....	....	....	[4571]	Magnesium
....	4564	4566	30	Iron	....	....
...	...	4564	50	Titanium	....	....
....	4559	4560	16	Iron	....	....
....	...	4556	50	Iron	....	....
....	4554	4554	50	Barium	....	....
....	4549	4550	80	Iron	....	....
....	{4534	4534	25	Iron	....	....
...	to			....	....	....
....	4502}	4502	90	Titanium	....	....
....	{4490	4492	160	Manganese	....	....
....		4490	45	Iron	. . .	....
....	4481	4482	10	Iron	4481	Magnesium
....		4472	2500	Cerium	....	....
....	4471}	4470	100	Iron	...	....
....	4445	4444	20	Iron	....	....
....	4436	....	....	....	4435	Calcium
....	4419	....	....	....	....	....
....	4385	4385	16	Ca., Ce.	....	....
....	4375	4376–75	39	Iron	. . .	....
....	4355	....	....	....	4354	Calcium
	{4347.8			....	....	....
4341	4340.6	4340 7	6500	Hydrogen	....	....
	4331.3}			....	.. .	....
[432]	4316	....	....	....	4318	Calcium
....	4296	....	....	....	....	....
....	4267	....	....	....	....	....
....	4246	4246	90	Iron	....	....
....	{4236	4236	150	Iron	....	....
	4227}			....	[4227]	Calcium
....	4209	[4216]	180	Calcium	. ..	....
....	4180	...	....	....	....	....
....	4166	...	....	....	4167	Magnesium
....	4126	....	....	....	....	....
	{4108			....	....	....
....	4102	4102	5000	Hydrogen	....	....
	4095}			....	....	....
....	4082	4078	50	Calcium	....	....

Near the centres of all the broad absorption lines shown on the photographs were comparatively fine bright lines. They were measurable at λ 5159, λ 5007, λ 4913, λ 4851 and λ 4431. They probably existed also at λ 6552, λ 6285, λ 5885 and λ 5307, since it was noted that the continuous spectrum showed faintly in the emission lines at those places, which effect was probably due more to the presence of the fine lines than to the very much fainter continuous spectrum shown in a few of the photographs.

If they existed on the more refrangible sides of other prominent bright lines, they were either concealed by the strong continuous spectrum, or, in certain regions, confused with other lines. We can probably say they existed in all the broad absorption lines, but we cannot say whether or not they existed quite independently of the absorption lines.

CONCLUSIONS.

It has generally been conceded that *Nova Aurigæ* was a system of at least two bodies, one giving rise to the system of very bright lines, the other to the system of broad absorption lines. On several photographs a very faint continuous spectrum showed as a background in the absorption lines. This probably belonged to the bright line spectrum or spectra. The strong continuous spectrum which masked many of the fainter bright lines probably belonged to the dark line spectrum. Nearly all the photographs show the F and Hγ bright lines to be double, with different degrees of clearness. There are signs of doubling in the strong lines in the green, and on the F negative of March 6 the line λ 4923 is distinctly separated into two nearly equal components.

Professor VOGEL has accounted for the observed phenomena in this manner: the fine bright lines within the broad absorption lines were due to reversals such as are sometimes observed in the spectra of Sun-spots, and were caused by eruptions of gases from the interior of the body furnishing the dark line spectrum; the doubling of the bright lines was due to the presence of two bodies possessing bright line spectra; and therefore *Nova* was a system of three bodies moving with very different velocities in the line of sight.

Dr. and Mrs. HUGGINS have suggested a further simplification, and have ingeniously explained the apparent doubling and great breadth of the bright lines by combining the reversion theory of ZÖLLNER and VOGEL with the tidal theory of

KLINKERFUES and WILSING. They consider *Nova* as a system of two bodies, one yielding a bright line spectrum and the other a dark line spectrum.*

The re-appearance of *Nova* as a planetary nebula, apparently with only one system of lines, favors a simple origin. But the fact that the present system of lines does not coincide with any one of the four former systems either makes the original spectrum more complex, or it shows conclusively that orbital motion has ensued. In the latter case much light must be thrown upon the question by continued observation of *Nova's* velocity, and considerable time may be required.

While the hypothesis of two bodies quite generally satisfies the observations, and has the further very great advantage of simplicity, there are a few not unimportant points furnished by the photographs which favor the existence of three or four bodies: two or three yielding bright line spectra and one a dark line spectrum. These points are:

First—The two components of the bright lines are much more clearly defined in the later photographs than in the earlier. This was partly but not wholly due to the decline of the continuous spectrum. The photographs taken early in February show the broad bright lines F and λ 4923 to be double only with difficulty. Two condensations, the more refrangible one being the stronger, show certainly, but not clearly. The F photograph of March 6 shows these lines as well defined doubles. In the line λ 4923 the two components are separated too widely to present the appearance of reversion, and the continuous spectrum shows only very thinly in that region.

Second—In all the double lines shown on the March 6 photographs the two components are nearly equal, while in the earlier photographs the more refrangible components were the stronger.

Third—There is some reason to believe that the intervals between the components were less in March than in February, though on the earlier negatives the measures were subject to considerable uncertainty, and photographs taken elsewhere do not seem to show this variation.

Fourth—The normal position of the fainter lines throughout the spectrum (as compared with the chromosphere spectrum) is

* See *Astronomy and Astro-Physics* for August, 1892.

evidence that they were mostly associated with the more refrangible components of the double lines, *and not with the double lines as a whole.*

Fifth—The fine bright lines appeared not only in the dark F and Hγ lines, but also in three dark lines in the green, all apparently in the same position relative to the principal series of bright lines.

Sixth—During the decline of *Nova* in brightness the continuous spectrum belonging mostly to the dark line star decreased more rapidly than the bright lines, while the fine bright lines decreased certainly no more rapidly than the principal bright lines.

The above evidence is far from conclusive, and is inserted now merely for completeness. On the hypothesis of four bodies, the principal system of bright lines was not displaced appreciably, and the star yielding it was practically at rest with reference to the solar system. Another system was displaced towards the red a distance corresponding to a velocity of recession of about 315 miles per second. The system of fine bright lines and likewise the system of dark lines were displaced towards the violet, a distance corresponding to a velocity of approach of about 400 miles per second.

THE PRESENT SPECTRUM.

The new star was clearly seen with the 36-inch telescope on April 24, when it was of the sixteenth magnitude or fainter. It was occasionally glimpsed late in the evening of April 26, when its altitude was small. Further observations were prevented by a three weeks' storm, at the close of which the star was too low in the west to be observed. The rapid decline in brightness made it probable that it would soon disappear from sight. But it was again observed by Professors HOLDEN and SCHAEBERLE and myself on August 17, when its magnitude was estimated 10.5. All the observers agreed that its appearance was different from that of other stars of the same magnitude, in that its disk was larger and its light duller. However, the moon was only a few degrees east of the star and the bright sky interfered with further observations on that point. A direct vision spectroscope of very small dispersion showed its spectrum to consist of three bright lines on a faint and continuous spectrum. The instrument did

not permit of measures being made to determine the wave-lengths, and the telescope was not available again for spectroscopy for several days. On August 19 (15 hours), with a more powerful spectroscope attached to the 12-inch telescope, the brightest line previously observed was resolved into three lines. These were at once recognized to be the three characteristic nebular lines, and thus the nebulous character of the object was established. By bringing lines into contact with a bar in the focus of the eye-piece and turning to β *Tauri* and *Venus* the wave-lengths were estimated to be 501, 496 and 486. The faint continuous spectrum was just visible.

The same morning Professor BARNARD, using the 36-inch telescope, observed the *Nova* as a nebula 3″ in diameter, with a tenth magnitude star in its centre. Thus, the nebulous character of the object was established independently by the two different methods.*

Further study of the spectrum with the large spectroscope has shown eighteen bright lines and a continuous spectrum corresponding to a star of the eleventh magnitude or fainter.

A table of the wave-lengths of the lines and their relative intensities is given below. The wave-lengths are reduced to the sun. The unmarked wave-lengths were obtained with the dense 60° flint prism and the 10½-inch observing telescope, using a magnifying power of 13.3. In obtaining those marked with an asterisk (*) the prism was replaced by a second order grating of 14,438 lines to the inch. In obtaining those marked thus (†) a first order grating was used. The one marked thus (‡) was obtained with a thallium compound prism. Those marked thus (§) were obtained photographically, using the 60° prism and replacing the the micrometer by a camera.

The photographs of October 12 and October 19 were obtained with a comparatively wide slit, and the wave-lengths are accurate to three places.

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* See also page 228 of the present number, under the dates April 4 and August 17.

Intensity	Aug. 20	Aug. 21	Aug. 22	Aug. 23	Aug. 30	Sept. 3	Sept. 4	Sept. 6	Sept. 7	Sept. 15	Sept. 22	Oct. 12	Oct. 19	Nov. 2	Nov. 3	Nov. 9	Nov. 16	Nov. 17	Nov. 24
1	5746	5751	5750	5750	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
0.2	.....	.....	.....	.....	557]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
0 3	.....	5268	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	5003 6	5003.7	5003.7	*5003 1	5002 9 ‡5002.3 *5002.24	5002.4	†5001.97 *5001 80 §5001.9	§5001.9 §5002.4	†5001 83 *5002.00 §5002	†5002.54 *5002.05 §5002.1	‡5002 34 †5002.39 *5002.70	†5003.67 *5003.57 §5003	‡5002.8 †5004.3 *5004.3 § 500	‡5004 49 †5004 32 *5004.34	‡5004.61 †5005.01 *5004 39	†5004.32 *5004.54	†5004.86 *5004.94	†5005.07 *5004.72	*5004.49 .....
3	4954	4953	4954	.....	.....	.....	§4953.3	§4953 3 §4952 1	§4953	§4954	.....	§4954	§ 495	.....	.....	.....	.....	.....	.....
1	486	4858.4	4858.3	.....	4857.3	4856.8	§4856 7	§4856.7	.....	§4857	.....	§ 486	§ 486	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 471	§ 471	.....	.....	.....	.....	.....	.....
0 4	4677	4684	4685	.....	.....	.....	.....	§4678	4680 §4685	.....	.....	§ 468	§ 468	.....	.....	.....	.....	.....	.....
0 7	4628	4633	4631	.....	.....	.....	.....	.....	4628 §4634	.....	.....	§ 464	§ 464	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 460	§ 460	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 451	§ 451	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	§4466	.....	.....	§ 447	§ 447	.....	.....	.....	.....	.....	.....
0 1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 438	§ 438	.....	.....	.....	.....	.....	.....
0.8	436	4357.1	4358 9	4358.0	.....	4358.9	.....	.....	§4360	§4358 4	.....	§ 436	§ 436	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	§4335.9	§4335 8	.....	§ 434	§ 434	.....	.....	.....	.....	.....	.....
0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 426	.....	.....	.....	.....	.....	.....
0 1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 423	.....	.....	.....	.....	.....	.....
0.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	§ 410	.....	.....	.....	.....	.....	.....

The spectrum is that of a planetary nebula, but there are a number of peculiarities which may prove to be significant. Nearly all the lines have been found to exist either in the spectrum of the planetary nebula Σ 6, or in that of the *Orion* nebula; the lines in *Nova's* spectrum being displaced four or five tenth-metres toward the violet (during August and September). The light, therefore, emanates from *one source*, which has been approaching the solar system with great velocity. It has not been possible to determine the velocity with great accuracy on account of the great breadth and diffuse character of the lines. With the second order grating and narrow slit, the line at λ 5003 is at least eight tenth-metres broad and the edges very diffuse.

There is no line at or near D_3, nor at C, within the reach of this telescope. The strong line in the yellow at λ 5750 has not yet been found in any other spectrum. It falls about midway between the bright lines in the WOLF–RAYET stars, which recent measures made here place at about λ 5813 and λ 5692. The lines at λ 5003, λ 4954, λ 4858 (Hβ), λ 4336 (Hγ) and λ 410 (Hδ) are the well-known lines common to all the nebulæ. The lines at λ 4682 shows the proper displacement when compared with the broad line λ 4687 in the nebulæ Σ 6, N. G. C., 7027 and N. G. C. 7662, and the bright blue band in one class of the WOLF–RAYET stars. The faint line λ 4466 is undoubtedly identical with the strong line λ 4472 in Σ 6 and the *Orion* nebula. This line is probably identical with the ever-present solar chromosphere line λ 4472. By far the brightest line shown on the photographs is that at λ 4359. It is about eight or ten times as intense as the Hγ line at λ 4336. This line exists in the three other nebulæ which I have thus far examined for it. In Σ 6 its wave-length obtained from two negatives is 4363, and its intensity is about one-tenth that of the Hγ line. In N. G. C. 7027 its wave-length from two negatives is 4363 and its intensity is about one-fourth that of Hγ. In a photograph of the spectrum of the *Orion* nebula (showing about 25 lines between λ 5007 and λ 3800) this line is shown at λ 4364, and its intensity is about one-twentieth of that Hγ. Two negatives of the spectrum of Σ 6 show a line at about λ 4636. Similarly, as stated above, nearly all the lines in *Nova's* spectrum are found in the spectrum of the nebulæ.

The relation of the present spectrum to the early one of February and March is not apparent. It is possible that the present lines with their present wave-lengths might have existed in the early

spectrum and have escaped detection; but such an hypothesis adds to the complexity of the original spectrum, and is, therefore, unsatisfactory. It is more probable that the present lines correspond to one of the former systems of bright lines, and that orbital motion has ensued, thereby changing the wave-lengths. The presence of the very bright line in the early spectrum at λ 5016 practically precludes a correspondence with any but the least refrangible series of bright lines. Such a correspondence is rendered more probable by the presence in the early spectrum of lines at λ 5885 (D_3 displaced?) and at λ 4969 (second nebular line displaced?).

The series of observations made upon the chief nebular line seem to show that the velocity of approach toward the Sun was increasing in August, was practically constant during the first half of September and since then has been decreasing. The table below contains the wave-lengths of the chief nebular line resulting from the several nights' observations together with the corresponding velocities of approach in miles per second:

Date.		λ	Velocity.
1892, Aug.	20	5003.6	—128
	21	3.7	125
	22	3.7	125
	23	3.1	147
	30	2.4	173
Sept.	3	2.4	173
	4	1.9	192
	6	2.1	184
	7	1.9	192
	15	2.2	180
	22	2.5	169
Oct.	12	3.6	128
	19	3.8	121
Nov.	2	4.4	99
	3	4.7	87
	9	4.4	99
	16	4.9	80
	17	4.9	80
	24	4.5	—95

There does not appear to have been much change during November; but of the reality of the change of nearly one hundred miles per second since September 6th, I have no doubt. It is probably the result of orbital motion, though no definite statement is now justified concerning the nature of the orbit.